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## An MAS-based implementation for semantic web services composition

### Abstract

Many information system developers face high cost in adopting service-oriented architectures because of the high cost of locating appropriate services to customise and integrate into their system. This chapter aims at reducing this cost by automating much of the composition and service selection effort. It illustrates the use of a peer-to-peer multi-agent system (MAS) to facilitate service selection with multiple quality of service properties. The system will use semantic enrichment of services in order to facilitate their identification and composition. With semantic-driven composition, services can be shared between teams of developers and across multiple organisations connected via the Internet. In this chapter, we focus on a conceptual framework for peer selection with a preliminary mathematical model and a selection process, so as to enhance the P2P-based service coordination system and its components.

### Keywords

web, mas, services, semantic, composition, implementation

### Disciplines

Engineering | Science and Technology Studies

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# An MAS-based Implementation for Semantic Web Services Composition

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**Abstract.** Many information systems developers face high cost in adopting service oriented architectures because of the high cost of locating appropriate services to customise and integrate into their system. This paper aims at reducing this cost by automating much of the composition and service selection effort. It illustrates the use of a Peer-Peer multi agent system (MAS) to facilitate service selection with multiple Quality of Service properties. The system will use semantic enrichment of services in order to facilitate their identification and composition. With semantic driven composition, services can be shared between teams of developers and across multiple organisations connected via the Internet. In this paper, we focus on a conceptual framework for peer selection with a preliminary mathematical model and a selection process, so as to enhance the P2P-based service coordination system and its components.

**Keywords:** semantic Web services, quality of service, peer-to-peer, ontology

## 1. Introduction

With the increasing popularity and growth of Web services, many researchers have been interested in developing effective e-service or e-business applications based on existing components for agent-based systems [10]. In a multi agent system (MAS) composed of a heterogeneous collection of agents with distinct knowledge-bases and capabilities, coordination and cooperation between agents facilitate the achievement of global goals that cannot be otherwise achieved by a single agent working in isolation [18]. The unique characteristics of a MAS have rendered most standard systems development methodologies inapplicable, leading to the development of Agent Oriented Software Engineering methodologies [2, 5].

However, along with a increasing number of Web services developed in agent-oriented decentralised environments, it's essential to consider the quality of service (QoS), such as response time, for agents when running business processes. It is obvious that the dynamics and heterogeneity of distributed services are extremely important to both service requestors and service providers. Nevertheless, most recent research is predominantly syntactic and has not truly incorporated semantic ontology approaches for service description and composition within a

realistic business context. The discovery and integration of a new service into an existing infrastructure is yet to be fully automated and currently requires significant human effort. As a result, it's problematic that traditional methodologies can effectively and autonomously conduct service discovery and composition in a complex dynamic environment. Moreover, the QoS specifications proposed in the literature (e.g., [11, 12, 17]) are yet to agree on common defining concepts.

A set of non-functional properties in Web Service Modelling Ontology (WSMO) [13] can be used as a discriminating factor to refine P2P-based Web services so as to provide a more reliable service selection in business workflows. In this paper, we present a scalable WSMO-based conceptual framework to describe QoS and other features of Web services in a P2P-based environment. We also sketch an automatic concomitant semantic Web services selection process to automatically find appropriate Web services that effectively fulfil the requestor's requirements. Hence, we design an approach to deal reasonably with the correlation between those requirement specifications, and to select the most appropriate peers that will foster a better service composition.

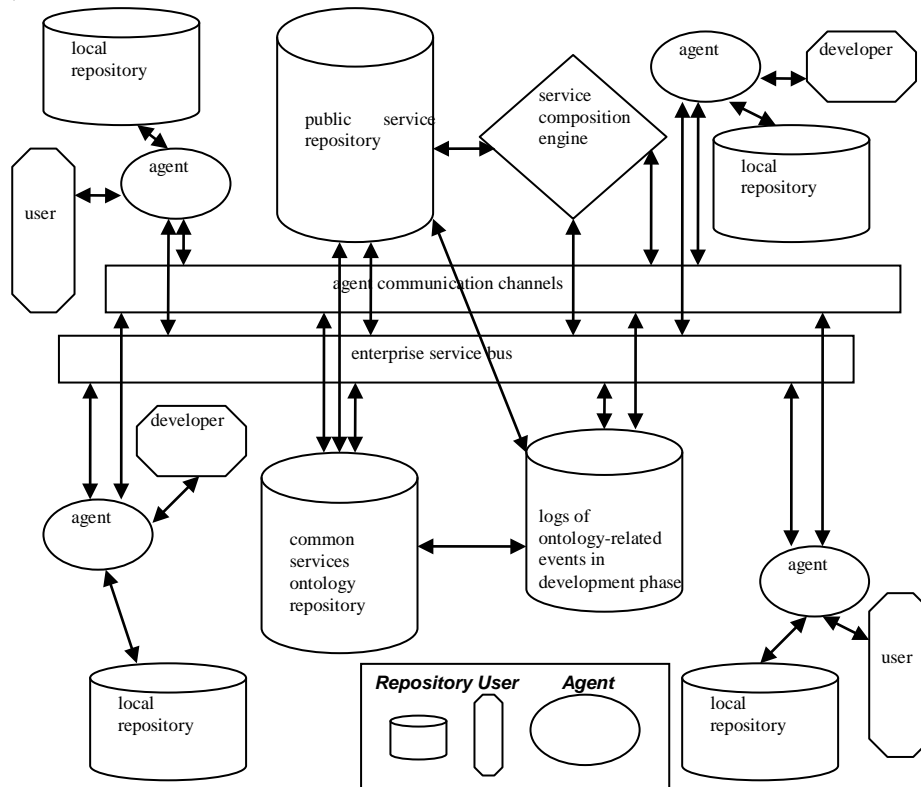
The rest of this paper is structured as follows. Section 2 illustrates our P2P architecture approach. Section 3 presents our QoS model and WSMO integration in our P2P framework, and sketches a practical solution for selecting appropriate peers with multiple properties, specified by our service quality conceptual model. Section 4 introduces our implementation of the peer assignment prototype and two algorithms for service selection. Section 5 concludes with a discussion of other related work.

## **2. P2P MAS to Compose Semantic Web Services**

Generally, in a P2P MAS architecture dedicated to sharing resources, the MAS acts as an interface to a set of resources distributed across a network. Each agent within the system typically acts as a gate keeper to a local repository of resources that it shares with other similar peer agents as they broadcast their requests. In this architecture, all agents co-operate fulfilling queries and having access to their repository of resources whenever a query received can be assisted by their local resources. Resources shared can be information (files of data, music etc.) e.g. as specified in systems similar to those in [5], [8] or services as in this paper.

In our proposed P2P framework, the MAS consisting of all cooperating agents responds to requests by a user (e.g. a service requester, a software developer, a human web user) who is also represented by an agent in the P2P network that acts on his/her behalf. This agent aims to fulfill the request, e.g. locates services and responds to queries by other similar agents. The collection of all these agents and agents assisting them in their tasks form a P2P community-based cooperative MAS. For composing services using their semantics, a P2P MAS is shown in Figure 1. An agent (an oblong in Figure 1) representing a user (a hexagon in Figure 1) has access to a knowledge base containing services/resources that the user is willing to share

with other users. Each service/file/resources (a cylinder in Figure 1) is identified by a unique identifier within the P2P network (e.g. Service identifier, HTML, PDF, music or video).



**Figure.1.** The P2P Multi agent system

As agents automatically interact on behalf of users seeking services to be composed, communities of interest begin to emerge. These communities may overlap. Providers and users of services may belong to more than one community; for instance a service to '*open an account*' may belong to the community of banking developers as well as that for insurance developers. As more and more services are composed, agents become more efficient and effective by interacting with the agents in the communities most likely to be able to provide them with service components. The P2P system is responsible for locating sites where candidate services are available, based on the previous requests made. The mediation between service requesters and providers is always done by the system. When an agent makes a service request, a candidate agent provider responds either by providing details about services it can supply, or refusing the service. When all responses are received, the requesting agent combines and refines the results to compile a list of

services that can be composed to fulfill the request. The requester agent can then select which services it wants to compose and initiates the composition.

After a successful composition a requester's knowledge base is updated to include the received and the composed services. Similarly for all agents involved in processing a service request, their knowledge bases are also updated with additional information reflecting the domain and attributes of the requester agent. This information is used in future service requests. That is, as agents interact they develop awareness of the services possessed by their peers and which peers may be interested in the services that they themselves have. Each agent keeps a record of its history of service sharing in order to evaluate the quality of services (QoS) and to use this for future service requests. The collection of this history is in essence a distributed QoS ontology distributed across providers. The QoS ontology will provide assessments of past queries and providers, and also information to make QoS estimates for members. It is used to produce a short list of candidate nodes for future queries, by calculating the similarity between the current query and a past query and its QoS. In a fully evolved P2P system, agents may use this QoS knowledge about other users' interests to request/negotiate for information from their peers when they do not know who has services of interest. New providers are constantly added to the history, expanding the user-agent's contact circle.

The proposed strategy of service sharing can be applied to any domain that can be prescribed by an ontology. The proposed P2P service execution system subsequently allows dynamic composition of Web services in a highly distributed and heterogeneous computing environment [3] that is adapted from [14] to highlight how ontologies can be used by taking advantage of semantically driven composition of services as is often advocated, e.g. in [15]. The system will provide, to both service requestors and service providers, the Quality of Service (QoS) evaluation. The system will identify the capability and performance of the service providers so as to enhance the service composition for service clients over the real distributed service network. Due to the complexity of QoS metrics [10, 17], a well-defined QoS service description does not actually exist. With a P2P architecture, the QoS is gauged by a service client through cooperative interactions with other peers that can potentially provide the service. The scope of using ontology-based profiles in this MAS development is possible since most of the current work focuses on the definition of a QoS ontology, vocabulary or measurements, and, to a lesser extent on a uniform evaluation of qualities. We propose to exploit Web Service Modelling Ontology (WSMO) [13] as complementary conceptual framework to create the QoS ontology to describe various perspectives on Web services, to facilitate integrating the services. In a specified domain, a Problem Solving Method [3] unit of analysis will nicely correspond to a service carried by an agent. The agents themselves can dynamically select PSM implementations that best suit the service or the QoS required to match the requested service level agreement (SLA). This selection will be made using a P2P searching mechanism to locate appropriate services from other peer agents. Cooperative communication between agents about their existing services, their past service requests and their performance will enable service requestors to locate the peer service provider with the most suitable QoS.

### 3. Conceptual QoS Model for Agents and Peers Selecting Services

WSMO defines four high-level notions that relate to semantic Web services, namely Ontologies, Goals, Mediators and Web services. *Ontologies* are viewed as formal and explicit specifications of shared conceptualizations [13]. They define a common agreed-upon terminology by providing concepts and relationships among the set of concepts from a real world domain. *Goals* are depictions of the expectations a service requestor may have when seeking for a service based on functionality, approach and quality of service. *Mediators* coordinate the heterogeneity problem that occurs between descriptions at different levels [16]: data level - different terminologies, protocol level - different communication behaviour between services, and process level - different business processes. WSMO defines four types of mediators: OO Mediators connect and mediate heterogeneous ontologies, GG Mediators connect Goals, WG Mediators link Web services to Goals, and WW Mediators connect Web services resolving mismatches between them. *Web services* are descriptions of services that are requested by service requestors, provided by service providers, and agreed between service providers and requesters.

Non-functional properties are usually utilised to describe non-functional aspects such as the creator and the creation date, and to provide natural-language descriptions. The four WSMO elements have their own non-functional properties. In this paper, however, our QoS extension is of the same nature as the notion of non-functional properties in “*Web services*”. In other words, we mainly introduce descriptors of QoS, such as performance, availability, and spatial features of distributed services. The incorporated QoS properties could also be used in parallel with existing non-functional attributes proposed by other WSMO elements. Thus, it is consistent to consider QoS parameters as non-functional properties.

We develop the non-functional properties in WSMO in order to support adaptive P2P-based service composition. Coordinator roles are allocated to agents in our framework at runtime (as described in Section 2). These organise the peer/agent selection process and distribute tasks. The resultant decentralised architecture is coordinated and self-managed effectively with services being allocated to peer/agent hosts, who are able to communicate with each other according to a real business process agreement or standard workflow definitions. In the rest of this paper, we present a more effective representation to enable peers to evaluate candidate composition (in Section 3.1) and select the most appropriate peers (in Section 3.2) for a requested service in a P2P information system. The P2P-based service selection problem can be generally formulated as the following: Consider  $P$  as a set of composing agents,  $P = \{p_1, p_2, \dots, p_N\}$ , where each  $P$  is an agent that gets involved in the composition of a number of services from the set  $S$  covering  $M$  atomic services,  $S = \{s_1, s_2, \dots, s_M\}$ . Each atomic service ( $s_j$ ) cannot be allocated to multiple Peers, so let  $x_{ij} = 1$  if atomic service ( $s_j$ ) is allocated to Peer

( $p_i$ ) and  $x_{ij} = 0$  otherwise, and a Peer ( $p_i$ ) can be allocated with a set of atomic services:  $A_{p_i} = \{s_1, s_2, \dots, s_{m_i}\}$ . Moreover, let  $Q_{p_i, s_j} = \langle RT, CT, AV, RB \rangle$  denote the QoS features of Peer ( $p_i$ ) for atomic service ( $s_j$ ), and  $\langle RT, CT, AV, RB \rangle$  represent ResponseTime, ComputationCost, Availability and Reliability. To optimally perform the service composition, the basic objective is to find a set of appropriate Peers that makes response time and computation cost as small as possible, while keeping the availability and reliability as large as possible. Therefore, 4 sub-objectives can be defined as  $\min(\sum RT)$ ,  $\min(\sum CT)$ ,  $\max(\prod AV)$  and  $\max(\prod RB)$ :

$$O_1 = \min(\sum_{p_i \in P} \sum_{k=1}^{m_i} Q_{p_i, s_k}(RT)), s_k \in A_{p_i} \quad (0)$$

$$O_2 = \min(\sum_{p_i \in P} \sum_{k=1}^{m_i} Q_{p_i, s_k}(CT)), s_k \in A_{p_i} \quad (0)$$

$$O_3 = \max(\prod_{p_i \in P} \prod_{k=1}^{m_i} Q_{p_i, s_k}(AV)), s_k \in A_{p_i} \quad (0)$$

$$O_4 = \max(\prod_{p_i \in P} \prod_{k=1}^{m_i} Q_{p_i, s_k}(RB)), s_k \in A_{p_i} \quad (0)$$

However, in order to consider the four objectives as a whole, it can be set as:

$$F = \max(\frac{w_3 \cdot O_3 + w_4 \cdot O_4}{w_1 \cdot O_1 + w_2 \cdot O_2}) \quad (0)$$

where  $\{w_1, w_2, w_3, w_4\}$  denote the weights for the four QoS properties:  $RT$ ,  $CT$ ,  $AV$  and  $RB$ . Subject to the following constraints:

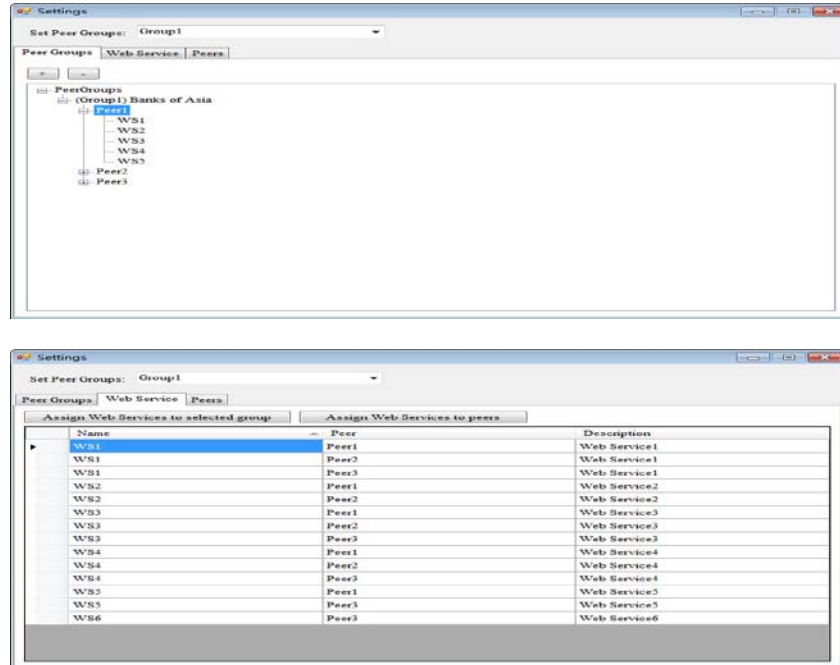
$$\sum_{i=1}^N x_{ij} = 1, \quad j = 1, 2, \dots, M, \quad \sum_{j=1}^M x_{ij} = m_i, \quad i = 1, 2, \dots, N, \quad \sum_{i=1}^N m_i = M$$

which respectively ensure there is no conflict between Peers to conduct atomic service allocation, and guarantee that the number of allocated atomic services of a peer are valid.

#### 4. System Implementation

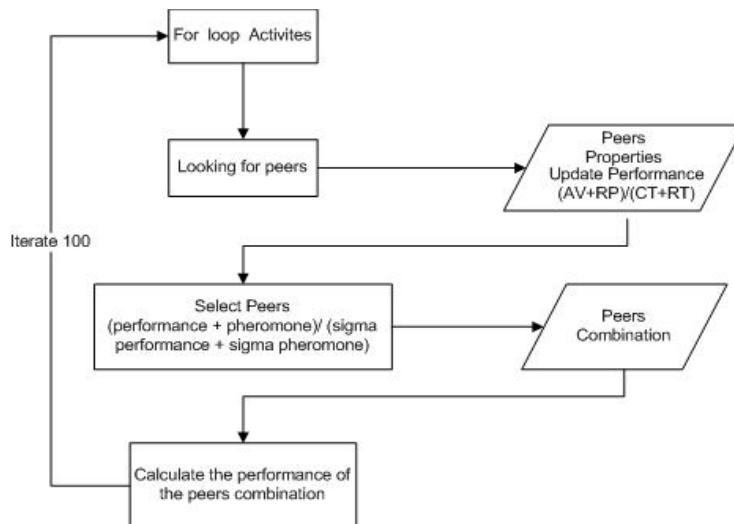
To enable the peers' coordinating agent to intelligently select peers and plan a whole composition process, we used the Ant Colony Algorithm (ACO) and Genetic Algorithm (GA) to test how composition can be achieved faster. Figure 2 is the basic configuration of the grouping and paring of peer's capability to serve a certain Web service with specific QoS agreements.





**Figure 2.** Configuration of Peer Groups and Peer-Service Pairs

When all parameters are set up for peers and services, we apply ACO and GA (shown in Figure 3 and 4 respectively).

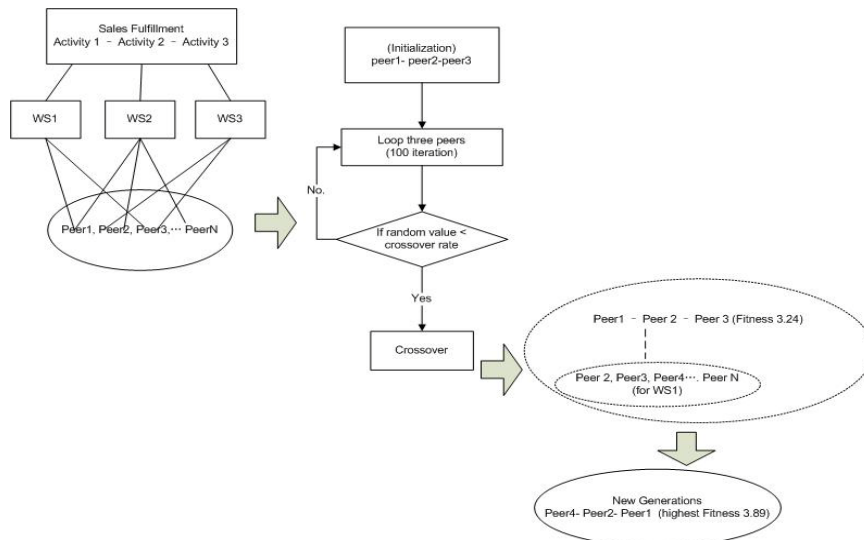


**Figure 3.** Diagram of ACO algorithm for Peer/Service Selection

Table 1 shows how fast the ACO algorithm can achieve a successful composition with regard to different number of activities in a composition (3, 30, 40, and 50) and number of supporting peers. The experiments assume there are 100 available atom Web services for selection and all peers are available to support these services.

**Table 1** Iterations of ACO Implementation for 100 Web services

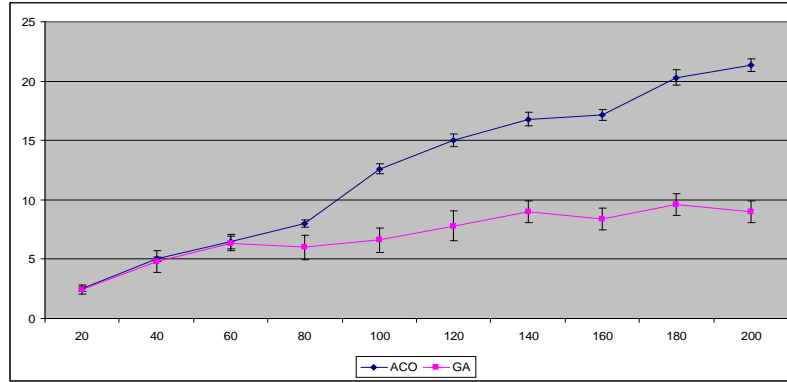
Number of activities	Number of Peers	Possibility of composition	Number of iteration
3	10	1000	14
3	20	8000	20
3	30	27000	31
3	40	64000	65
<b>3</b>	<b>50</b>	<b>125000</b>	<b>97</b>
3	60	216000	369
3	70	343000	491
<b>30</b>	<b>50</b>	<b>50<sup>30</sup></b>	<b>324</b>
<b>40</b>	<b>50</b>	<b>50<sup>40</sup></b>	<b>422</b>
<b>50</b>	<b>50</b>	<b>50<sup>50</sup></b>	<b>514</b>



**Figure 4.** Diagram of GA Algorithm for Peer/Service Selection

The two algorithms were compared and evaluated for average values of running

the objective function for 30 times with standard deviation and the value of statistical significance ( $p < 0.05$ ).



**Figure 5:** Comparison to the quality of service composition

As shown in Figure 5, when the scale of the MAS peers is less than 60, the average quality of solution of the two algorithms tends to be similar. However, when the scale increases, the performance of GA decreases while the ACO algorithm remains stable.

## 5. Discussion and conclusion

This paper aimed to ease semantic Web services development for business process management systems. Towards this, it focussed on QoS-aware service selection and composition which has been subject to considerable attention recently e.g [19-21]. Functional and non-functional properties are typically seen as the two essential aspects for requirement analysis [4] and they are typically used to describe the semantic of Web services. Functional properties describe how a web service meets the functional requirements of an anticipated service while non-functional properties describe the performance of the service. This distinction underlies many web services identification frameworks which in turn can be implemented in common ontology languages such as OWL-S [19-20]. Such representations form the ontological description of services and the design of the selection process. Our previous prototype in [19] was limited to a single specification. It only considered “ResponseTime” as the selection criterion, which was not sufficient for effective services composition. This paper extends the description of non-functional properties via a model-driven WSMO specification, and also presents an approach for the coordinator to automatically identify the best peers through unifying qualities and properties.

Our work is in line with other works focussing on the development of QoS ontology languages and vocabularies, as well as the identification of various QoS

metrics and their measurements with respect to semantic e-services e.g. [21], [6], [1] or [12]. We presented a QoS ontology to complement the DAML-S [1] ontology in order to provide a better QoS metrics model. Works, [6] and [12], emphasized a definition of QoS aspects and metrics, but have not included the extensible aspects in QoS, such as incorporating Geo features which we earlier proposed in [19]. In [12], all of the possible quality requirements were introduced and divided into several categories, such as runtime-related, transaction support related, configuration management and cost related, and security-related QoS. Both [6] and [12] present their definitions and possible determinants. Unfortunately, they are too abstract to suit the implementation requirement. They did not tend to present a practical approach for real services selection. In [11] and [17], the authors focused on the creation of QoS ontology models, which proposed QoS ontology frameworks aimed at formally describing arbitrary QoS parameters. Additionally, [7] and [9] attempted to conduct a proper evaluation framework and proposed QoS-based service selection, despite the authors failing to present how to validate the effectiveness of such a framework or algorithm. In contrast, our proposed a P2P-based service selection framework automates the basic problem of service selection using a representation with multiple properties, and augments the WSMO description by involving typical QoS perspectives. Our service peer selection model will be further modernized in the future by focusing on concrete and detailed geographic features for location-based services. This will improve our framework for P2P-based workflow under more dynamic circumstances more effectively.

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